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APPLICATION NUMBER: ***60/536,535***
FILING DATE: ***January 15, 2004***
RELATED PCT APPLICATION NUMBER: ***PCT/US05/01233***

UNITED STATES PATENT AND TRADEMARK OFFICE
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

19587 U.S. PTO
60/536535

Express Mail Label No.

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Arnon	HIRSHBERG	Haifa, Israel

Additional inventors are being named on the 1 *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

INTEGRAL BRITTLENES TEST DEVICE AND METHOD

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

☐ Customer Number:

OR

☑ Firm or Individual Name	c/o Miller - Sieradzki, advocates & patent attorneys				
Address	P.O.B. 6145				
Address					
City	Haifa	State		Zip	31061
Country	Israel	Telephone	972-4-8386149	Fax	972-4-8383548

ENCLOSED APPLICATION PARTS *(check all that apply)*

☑ Specification *Number of Pages* 5
☑ Drawing(s) *Number of Sheets* 2
☐ Application Date Sheet. See 37 CFR 1.76
☐ CD(s), Number
☐ Other (specify)

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☑ Applicant claims small entity status. See 37 CFR 1.27.
☐ A check or money order is enclosed to cover the filing fees.
☐ The Director is herby authorized to charge filing fees or credit any overpayment to Deposit Account Number:
☑ Payment by credit card. Form PTO-2038 is attached.

FILING FEE Amount ($): 80.00 USD

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☑ No.
☐ Yes, the name of the U.S. Government agency and the Government contract number are:

Respectfully submitted,

SIGNATURE [signature]

TYPED or PRINTED NAME Arnon HIRSHBERG

TELEPHONE 972-4-8295582

Date Jan. 8, 2003

REGISTRATION NO. (if appropriate)

Docket Number: 1068/38

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PROVISIONAL APPLICATION COVER SHEET
Additional Page

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Docket Number

INVENTOR(S)/APPLICANT(S)

Given Name (first and middle [if any])	Family or Surname	Residence (City and either State or Foreign Country)
Matan	NAFTALI	Yoqne'am, Israel
David	ELATA	Haifa, Israel

[Page 2 of 2]

Number 1 of 1

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מילר-שרצקי
משרד עורכי דין ועורכי פטנטים
Miller-Si radzki
advocates & patent attorneys

Yosef Carmel Miller, advocate
Doron Sieradzki, advocate & patent attorney

Dina Back-Frimer, advocate
Farha Jubran, advocate

יוסף כרמל מילר, עורך דין
דורון שרצקי, עורך דין ועורך פטנטים

דינה בק-פרימר, עורכת דין
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Dear Sirs,

Re: New US Provisional Patent Application
HIRSHBERG et al.
<u>INTEGRAL BRITTLENES TEST DEVICE AND METHOD</u>

Enclosed please find attached a new provisional patent application.

Enclosed documentation includes:

1) Specification – 5 pages (2 copies)
2) Drawings – 2 sheets (2 copies)
3) Provisional Application for Patent Cover Sheet (form PTO/SB/16), duly signed by first named inventor.
4) Credit Card Payment Form

Please direct all correspondence in this case to the first named inventor:
Arnon HIRSHBERG
c/o Miller – Sieradzki
P.O.B. 6145
Haifa 31061
<u>Israel</u>

Very truly yours,

Doron Sieradzki

INTEGRAL BRITTLENES TEST DEVICE AND METHOD

The present invention relates to an integral brittleness test device and method for measuring the strength of brittle, deformable microstructures.

Problem Solved by the Invention and its environment:

The present invention relates to the reliability of brittle, deformable structures that are prevalent in Micro-Electro-Mechanical-Systems (MEMS). Main aspects of the present invention address the following considerations: 1) measuring the ultimate strength of the structure in question (i.e., σ_{uts}). 2) conducting said measurement without the necessity of measuring forces or displacements. 3) Conducting said measurement without the necessity of packaging or special handling of the test device (i.e., in microsystems the test can be performed at the "wafer level" without requiring dicing).

Characterization of the strength of deformable elements in MEMS is important for design, and for estimation of reliability. The strength of such elements depends on mechanical properties of the structural material and is strongly affected by the surface texture that is formed during the fabrication process.

Closest Known Related Technology:

Current techniques for characterizing the strength of structural elements in MEMS devices require real-time measurement of displacements and measurement of the applied forces. In some devices (see Fig.1) a "Dog-bone" test structure is axially tensioned up to failure [1]. In these devices failure can occur anywhere along the specimen. In other devices a cantilevered beam is deflected up to failure (see Fig.2), which inevitably occurs at the clamped edge [2]. In both techniques, the maximal applied force is either directly measured, or is deduced from direct measurement of the deflection (and known elastic constants of the tested material). Also, in both techniques the exact location of the failure provides no additional information on the mechanical properties of the structural material.

Novelty

The new test device and method require no measurement of the applied forces or of the resulting deformation. They only require a measurement of the length of the remaining ligament. Due to the simplicity involved in the present invention, the integral test device can be used at the wafer-level (i.e., before dicing) and may be used to calibrate and examine the repeatability of the micromachining process.

Advantag s of th Inv ntion:

The present invention has several advantages over the conventional solutions to the problems described above.

1) It only requires a measurement of the length of the remaining ligament, In contrast to previous techniques that require dedicated equipment to measure forces or displacements.
2) Due to the simplicity of its operation, this device can be used at the wafer-level (i.e., before dicing), In contrast to previous techniques that require delicate handling or expensive packaging process.
3) May be used to calibrate and examine the repeatability of the micromachining process.
4) May be used to characterize the uniformity in serial processing of wafers.

Full Description of the Invention:

Cantilever beams are deformed up to failure by application of an unmeasured force. The ultimate tensile strength of the beams is directly deduced from the length of the remaining intact ligament of the broken beam.

The maximal tensile stress in a bent beam is equal to the product of the beam curvature, half of the beam width (h in Fig 3a), and the effective elastic modulus. The elastic modulus of the silicon is known and the beam width is measured (for example by optical means). By knowing the exact curvature of the beam at the point of failure, the ultimate tensile strength may be deduced. The cantilever beam in the new test device is wrapped over a wall with prescribed curvature. (For example if the wall is designed such that its curvature is linearly proportional to the circumferential distance from the clamped edge of the beam (see Fig.3). Accordingly, when the beam fails (breaks), the length of the

remaining ligament of the beam is linearly proportional to the ultimate tensile strength.) Note that the prescribed curvature does not necessarily have to be linearly changing curvature, and in fact any prescribed curvature is suitable.

The wrapping of the beam over the curved wall is preferably performed by a micro-manipulator, and the length of the remaining ligament is preferably optically measured (see Fig.3b).

The new device (see Fig.3) may be fabricated from mono-crystalline Silicon with known mechanical properties. However, the beams in this device are preferably micromachined using DRIE - Deep Reactive Ion Etching and their strength depends on the texture of the surface created by this fabrication process.

Many devices are fabricated using this process and usually the process parameters are found by trail and error or by previous experience. This present device and method can shorten the tuning time required to stabilize the process by deducing a direct result for the maximum strength capabilities.

During production this present device and method can be used as a characteristic for the whole wafer, to decide if the wafer continues the process flow or is thrown away (as in "pass / fail" test).

The present invention may be incorporated in the fabrication of wafers by way of including the device in a wafer in order to facilitate in-situ tests.

CLAIMS

1. A device for measuring the tensile strength of a brittle material, the device comprising:

a main body with an integral cantilever beam, the main body having a curved wall, the curved wall designed such that its curvature is known .

2. A method for measuring the tensile strength of a brittle material, the method comprising:

imposing a changeable curvature over a cantilever beam, up to failure (break) of the beam and by measuring the remaining ligament length, deducing the maximum tensile strength.

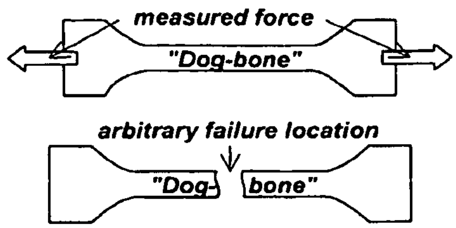

Figure 1: A "Dog-bone" tension test device. The applied force at failure must be measured. The location of failure provides no additional information.

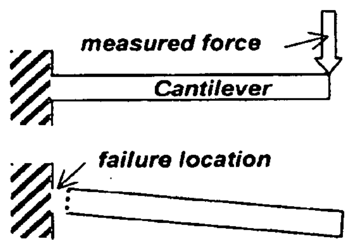

Figure 2: A cantilever test structure. The applied force must be measured. The failure always occurs at the clamped edge.

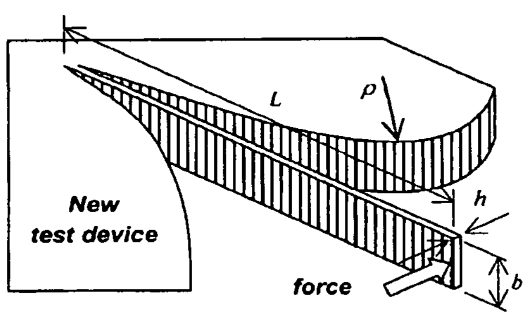

Figure 3a: A schematic description of the new test device. The curvature of the cylindrical wall increases linearly with distance from the clamped edge of the beam.

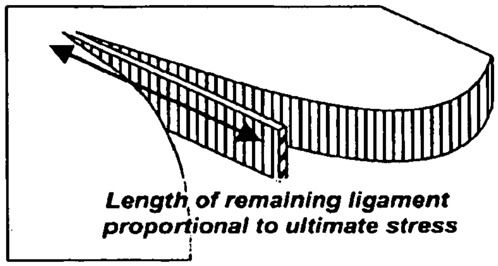

Figure 3b: The length of the remaining ligament after failure is linearly proportional to the ultimate strength of the structural material.